BGS13SL9

Performance of SP3T RF Switch

Mobile Phone Applications

Application Note AN301

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RF and Protection Devices

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Previous Revision: prev. Rev. 1.0

Page	Subjects (major changes since last revision)
7	Table 1 corrected

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1 Introduction

The BGS13SL9 RF MOS switch is designed for RF switch applications in mobile phones. Any of the 3 ports can be used as termination of the diversity antenna handling up to 30 dBm.

This SP3T offers low insertion loss and high robustness against interferer signals at the antenna port and low harmonic generation in termination mode. The on-chip controller integrates CMOS logic and level shifters, driven by control inputs from 1.5 V to Vdd. The BGS13SL9 RF Switch is manufactured in Infineon's patented MOS technology, offering the performance of GaAs with the economy and integration of conventional CMOS including the inherent higher ESD robustness. The device has a very small size of only 1.15 x 1.15 mm² and a maximum height of 0.31 mm.

No decoupling capacitors are required in typical applications as long as no DC is applied to any RF port.

2 BGS13SL9 Features

2.1 Main Features

- 3 high-linearity TRx paths with power handling capability of up to 30 dBm
- High switching speed, ideal for WLAN and Bluetooth applications
- All ports fully bi-directional
- No decoupling capacitors required if no DC applied on RF lines
- Low insertion loss
- Low harmonic generation
- High port-to-port-isolation
- 0.1 to 3 GHz coverage
- High ESD robustness
- On-chip control logic
- Very small leadless and halogen free package TSLP-9-3 (1.15 x 1.15mm^2) with super low height of 0.31 mm
- RoHS compliant package

2.2 Functional Diagram

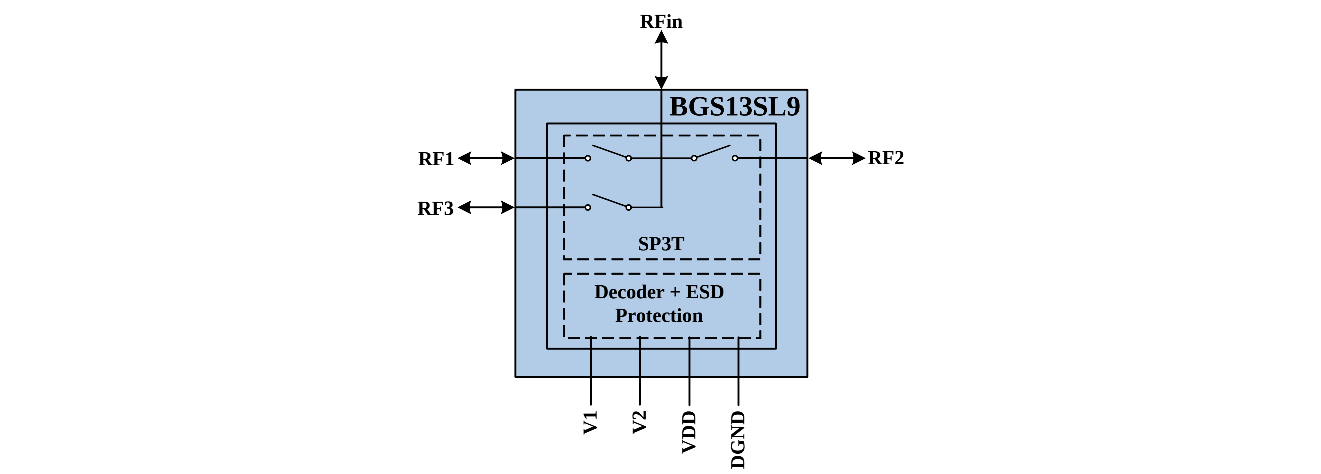

Figure 1 BGS13SL9 Functional Diagram

2.3 Pin Configuration

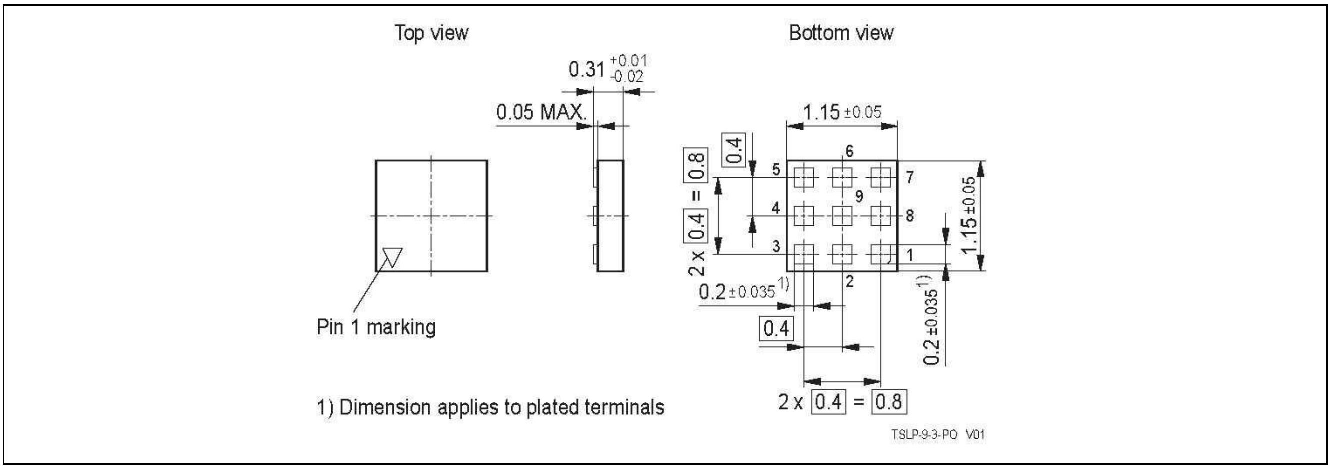

Figure 2 Pin configuration

2.4 Pin Description

Table 1 Pin Description (top view)

Pin NO	Name	Pin Type	Function
1	V1	I	Control Pin 1
2	RF3	I/O	RF port 3
3	RF1	I/O	RF port 1
4	RFIN	I/O	RF port In
5	RF2	I/O	RF port 2
6	DGND	GND	Digital Ground
7	Vdd	PWR	Supply Voltage
8	V2	I	Control Pin 2
9	GND	GND	Ground

3 Application

3.1 Application Bluetooth – WiFi Switch

Below a general application diagram of a combined WLAN - Bluetooth system is shown. For the low Band WLAN and Bluetooth switching the Infineon BGS13SL6 is applied. The high band switch is the BGS12SN6.

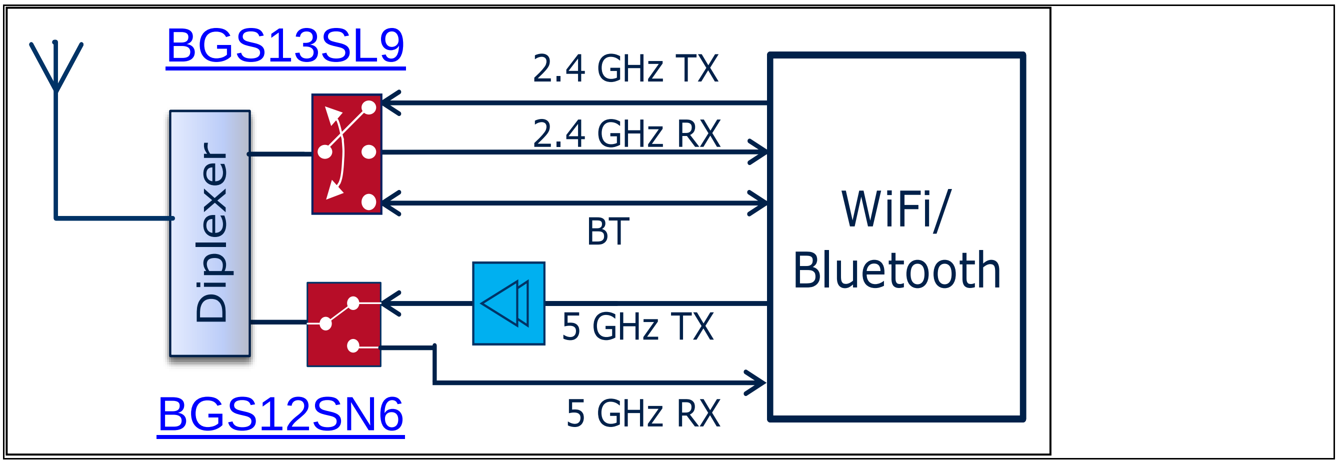

Figure 3 Application WLAN- Bluetooth

3.2 Application Post PA Band Switch

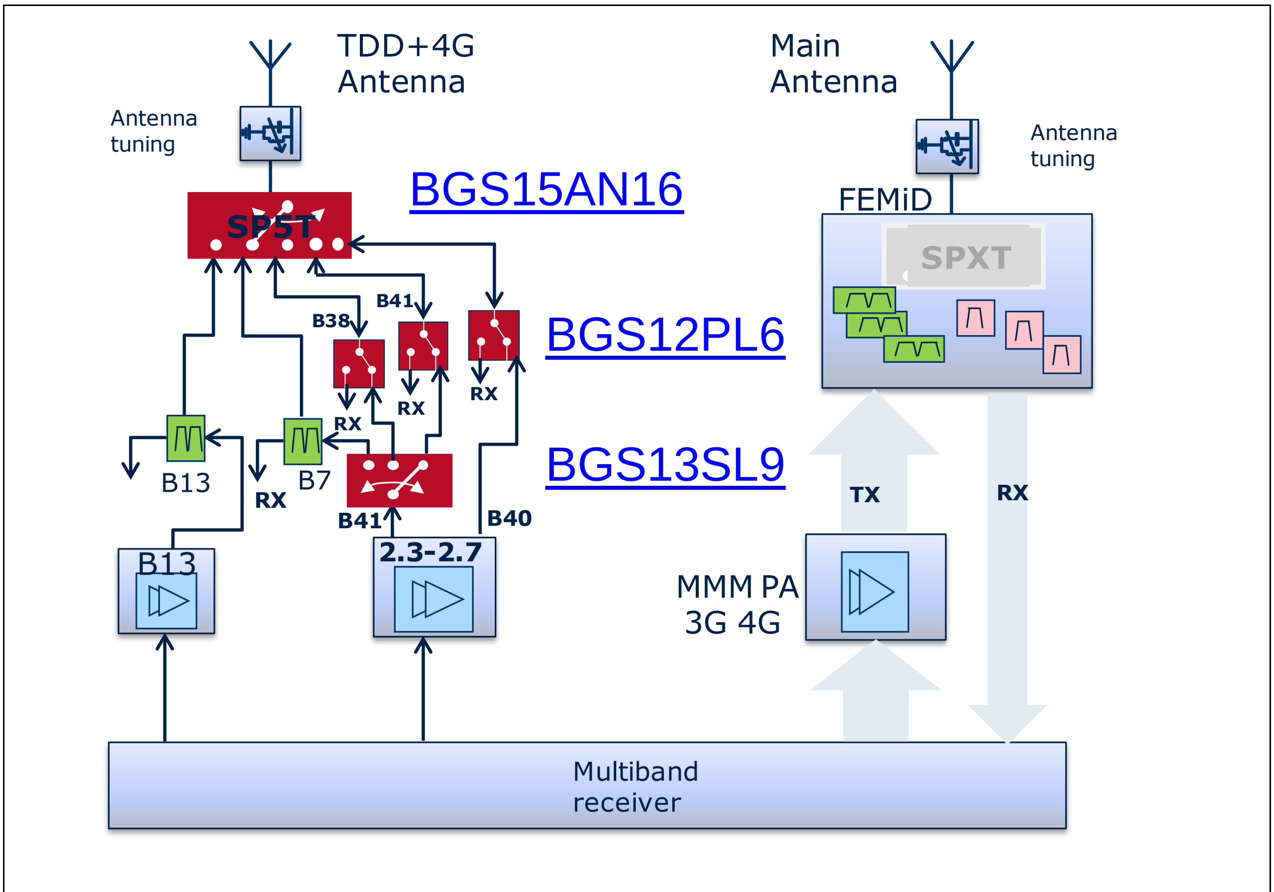

Figure 4 Application Smart Phone Block Diagram

This application of a multiband smart phone show the big amount of RF Switches, used for the band- and TX/RX switching. Infineon can address the SP5T BGS15AN16 for the antenna switch, the BGS12PL6 for the TX / RX switching and the BGS13SL9 for the post PA band selecting switch. Especially this RF switch from Infineon is described in the application note.

3.3 Application Board

Below is a picture of the evaluation board used for the measurements (Figure 5). The board is designed so that all connecting 50 Ohm lines have the same length.

In order to get accurate values for the insertion loss of the BGS13SL6 all influences and losses of the evaluation board, lines and connectors have to be eliminated. Therefore a separate de-embedding board, representing the line length is necessary (Figure 6).

The calibration of the network analyser (NWA) is done in severall steps:

- Perform full calibration on all NWA ports.
- Attach empty SMA connector at port 2 and perform “open” port extension. Turn port extensions on.
- Connect the “half” de-embedding board (Figure 6 left board) between port1 and port2, store this as a s-parameter (.s2p) file.
- Turn all port extentions off.
- Load the stored s-parameter file as de-embedding file for all used NWA ports
- Switch all port extentions on
- Check insertion loss with the de-embedding through board (Figure 6 right board)

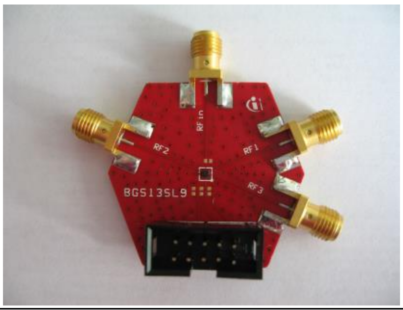

Figure 5 Layout of the application board

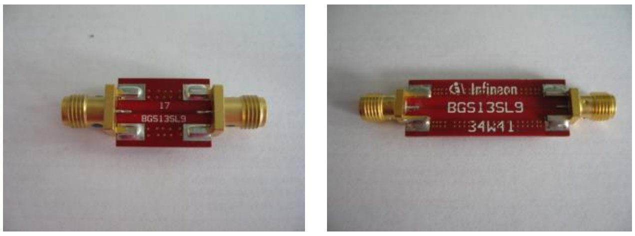

Figure 6 Layout of de-embedding boards

The construction of the PCB is shown in Figure 7.

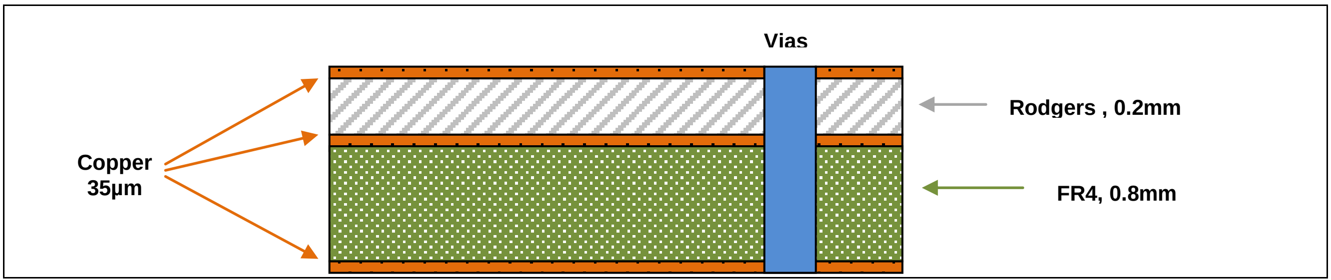

Figure 7 PCB layer information

4 Small Signal Characteristics

The small signal characteristics are measured at 25 °C with a Network analyzer connected to an automatic multiport switch box.

4.1 Forward Transmission from Antenna to the respective RF port with all other ports terminated with 50Ω

Table 2 Forward Transmission (dB)

Frequency (MHz)	824	915	1000	1710	1910	2170	2690
RF1	-0.33	-0.34	-0.34	-0.39	-0.42	-0.47	-0.64
RF2	-0.34	-0.35	-0.35	-0.39	-0.42	-0.46	-0.6
RF3	-0.34	-0.35	-0.35	-0.39	-0.42	-0.47	-0.64

4.2 Reflection coefficient measured at the Antenna port with all other ports terminated at 50Ω

Table 3 Reflection Coefficient (dB)

Frequency (MHz)	824	915	1000	1710	1910	2170	2690
RF1	-30.6	-29.7	-28.8	-20.5	-18.9	-17	-13.6
RF2	-31.3	-30.1	-28.9	-21.6	-19.8	-17.8	-14.4
RF3	-31.9	-31	-30.6	-21.9	-20.1	-17.9	-14.4

4.3 Forward Transmission

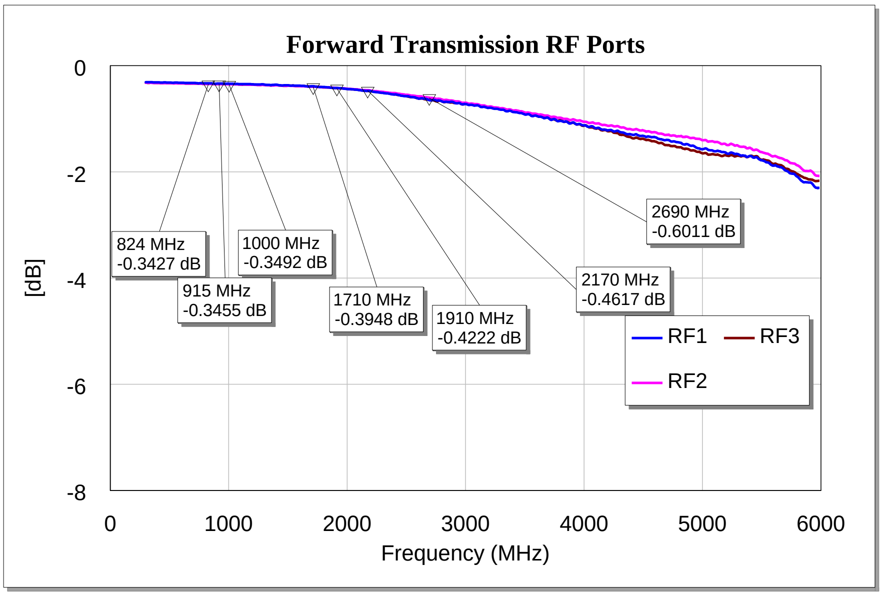

Figure 8 Forward Transmission Curves for RF Ports

4.4 Reflection RFin Port

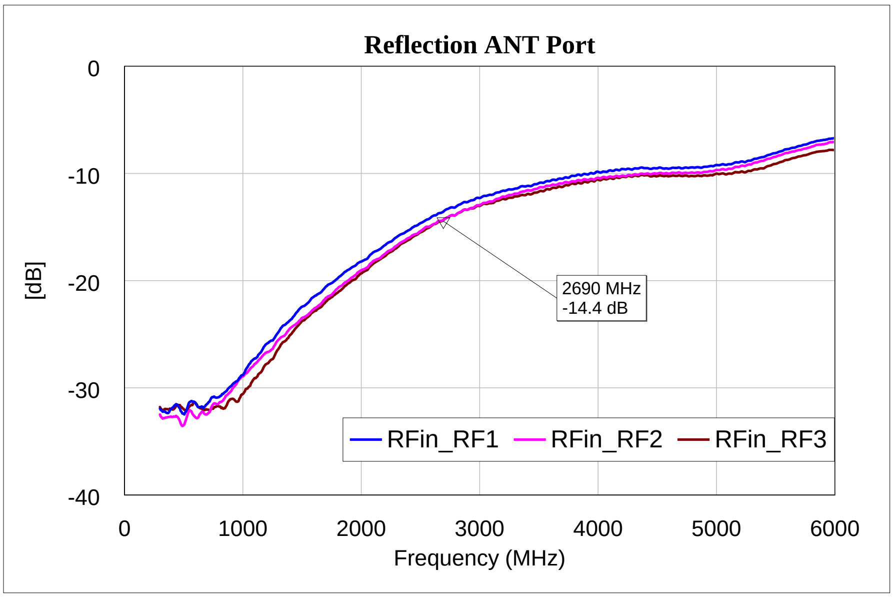

Figure 9 Reflction RFin Port

4.5 Isolation RF1

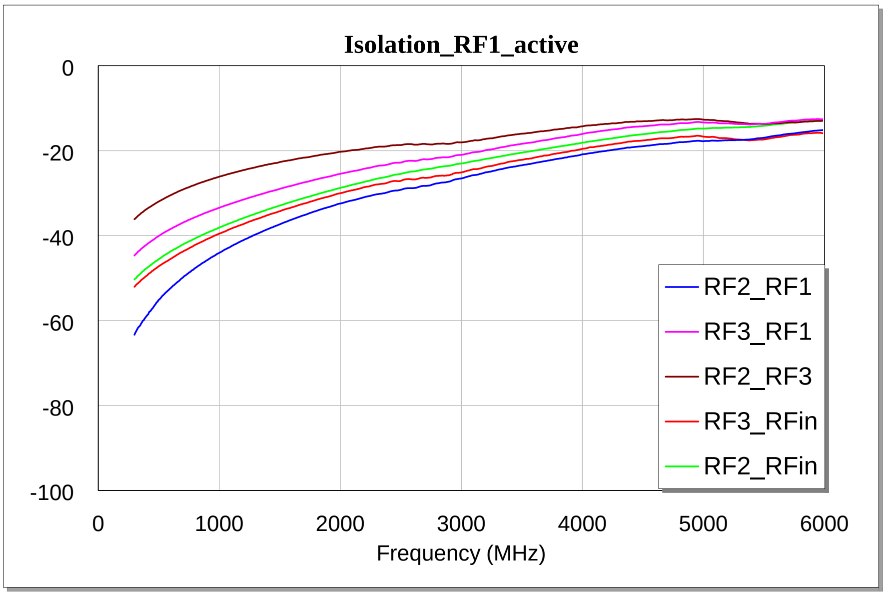

Figure 10 Isolation RF1

4.6 Isolation RF2

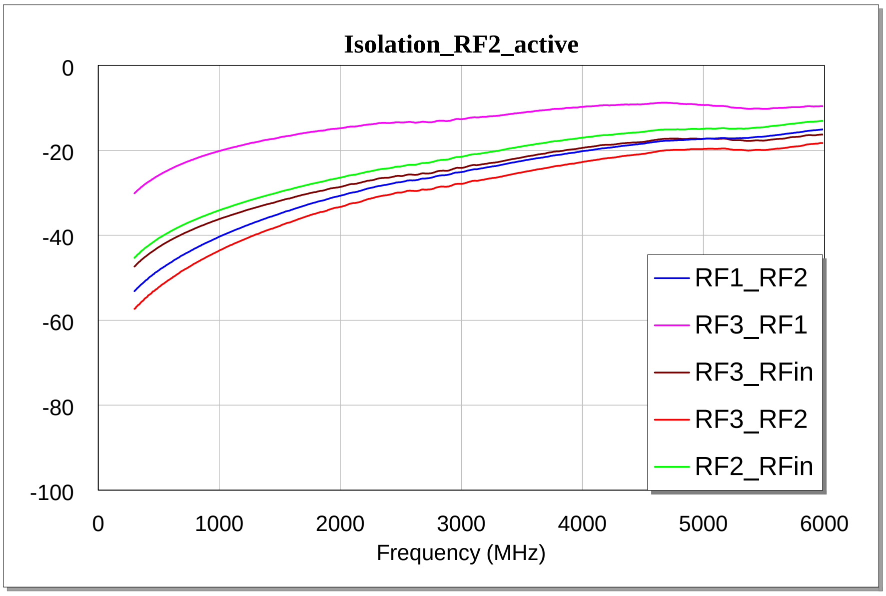

Figure 11 Isolation RF2

4.7 Isolation RF3

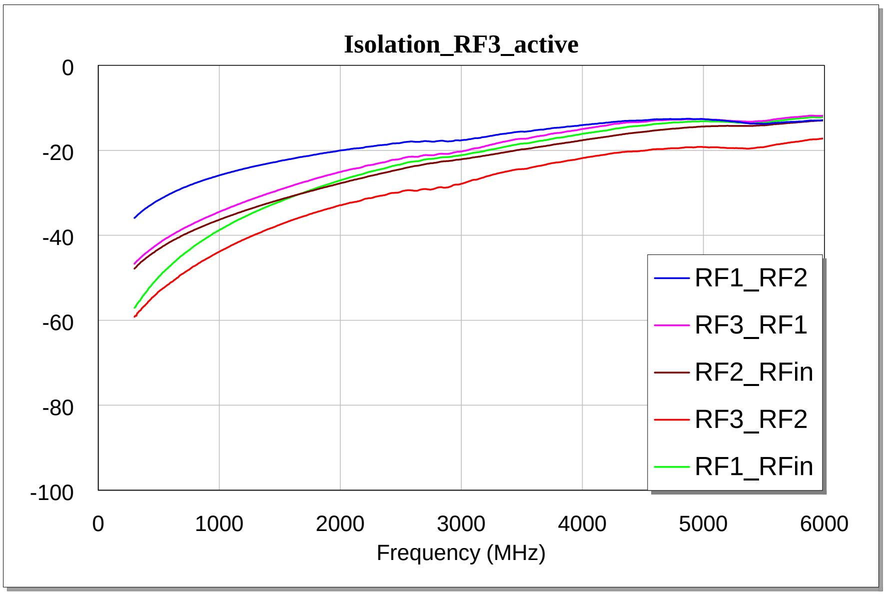

Figure 12 Isolation RF3

5 Intermodulation

Another very important parameter of a RF switch is the large signal capability. One of the possible intermodulation scenarios is shown in Figure 13. The transmission (Tx) signal from the main antenna is coupled into the diversity antenna with with high power.This signal (20 dBm) and a received Jammer signal (-15 dBm) are entering the switch.

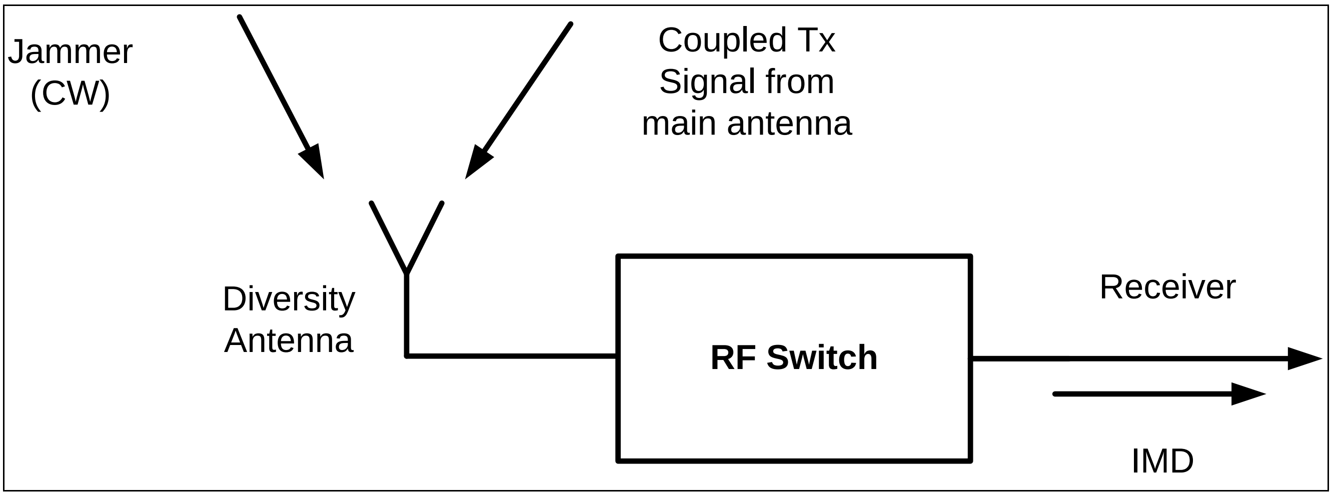

Figure 13 Block diagram of RF Switch intermodulation

Special combinations of TX and Jammer signal are producing intermodulation products 2^{nd} and 3rd order, which fall in the RX band and disturb the wanted RX signal.

In Table 4 frequencies for 3 bands and the linearity specifications for an undisturbed communication are given.

Table 4 Test conditions and specifications of IMD measurements

Test Conditions (Tx = +20dBm, Bl = -15dBm,freq.in MHz,@25°C)						Linearity Specification			
Band	Tx Freq.	Rx Freq.	IMD2 Low Jammer 1	IMD3 Jammer 2	IMD2 High Jammer 3	IM2 (dBm)	IIP2 (dBm)	IM3 (dBm)	IIP3 (dBm)
850	836.5	881.5	45	791.5	1718	**-105**	110	**-105**	65
1900	1880	1960	80	1800	3840	**-105**	110	**-105**	65
2100	1950	2140	190	1760	4090	**-105**	110	**-105**	65

The test setup for the IMD measurements has to provide a very high isolation between RX and TX signals. As an example the test set-up and the results for the high band are shown (Figure 14 and Table 6).

For the RX / TX separation a professional duplexer with 80 dB isolation is used.

In Table 5 the results for High band are given. For each distortion scenario there is a min and a max value given. This variation is caused by a phase shifter connected between switch and duplexer. In the test set-up the phase shifter represents a no ideal matching of the switch to 50 Ohm.

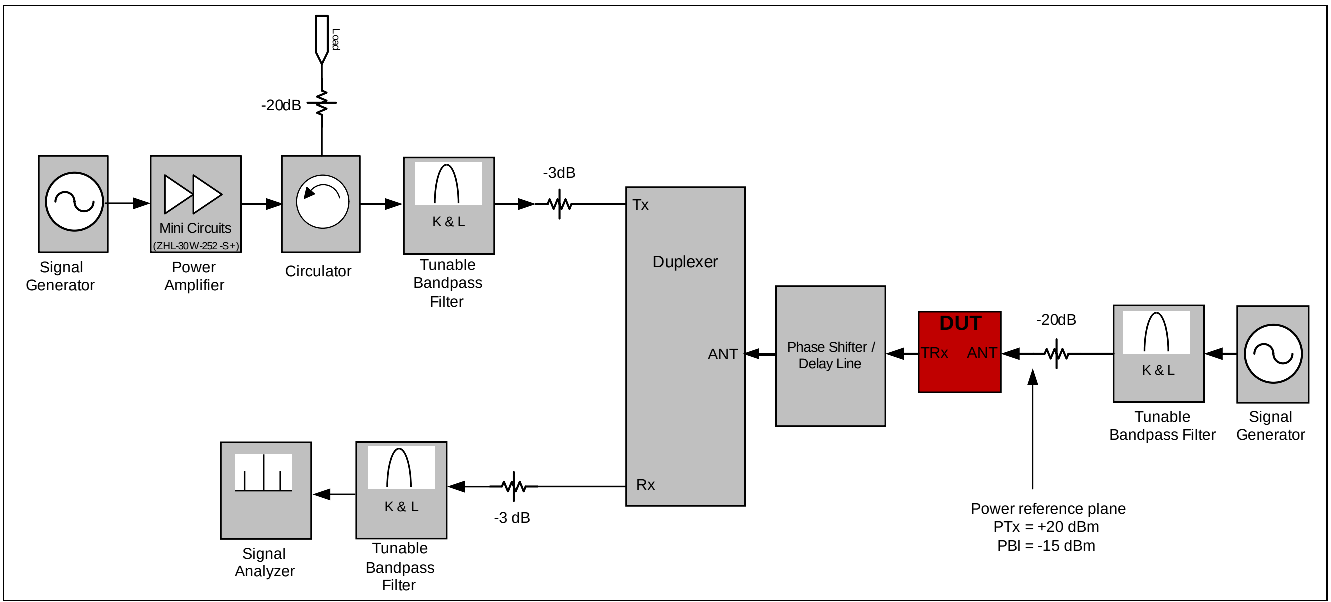

Figure 14 Test set-up for IMD Measurements

Table 5 IMD Results Band 1 (Tx 1950 MHz, Rx 2140 MHz, P_{BL} = -15 dBm, V_{dd} = 3Volt)

Band I	Ant –RF1		Ant – RF2		Ant – RF3	
	Min	Max	Min	Max	Min	Max
IMD2Low f_b=190MHz,P_{TX}=10dBm	-118.25	-107.46	-116.29	-106.49	-116.39	-106.04
IMD2High f_b=4090MHz,P_{TX}=10dBm	-108.73	-106.52	-109.24	-106.25	-108.45	-106.69
IMD3 f_b=1760MHz,P_{TX}=10dBm	-120.61	-113.93	-120.67	-113.63	-118.17	-108.01

Table 6 IMD Results Band V (Tx 836.5MHz, Rx 881.5 MHz, P_{BL} = -15 dBm, V_{dd} = 3Volt)

Band V	Ant – RF1		Ant – RF2		Ant – RF3	
	Min	Max	Min	Max	Min	Max
IMD2Low f_b=45MHz,P_{TX}=10dBm	-114.48	-109.39	-113.84	-108.95	-113.08	-108.25
IMD2High f_b=1718MHz,P_{TX}=10dBm	-110.64	-107.34	-110.79	-107.42	-109.53	-105.79
IMD3 f_b=791.5MHz,P_{TX}=10dBm	-118.99	-115.97	-119.97	-115.47	-122.33	-115.91

6 Harmonic Generation

Harmonic generation is another important parameter for the characterization of a RF switch. RF switches have to deal with high RF levels, up to 33 dBm. With this high RF power at the input of the switch harmonics are generated. This harmonics (2nd and 3rd) can disturb the other reception bands or cause distortion in other RF applications (GPS, WLan) within the mobile phone.

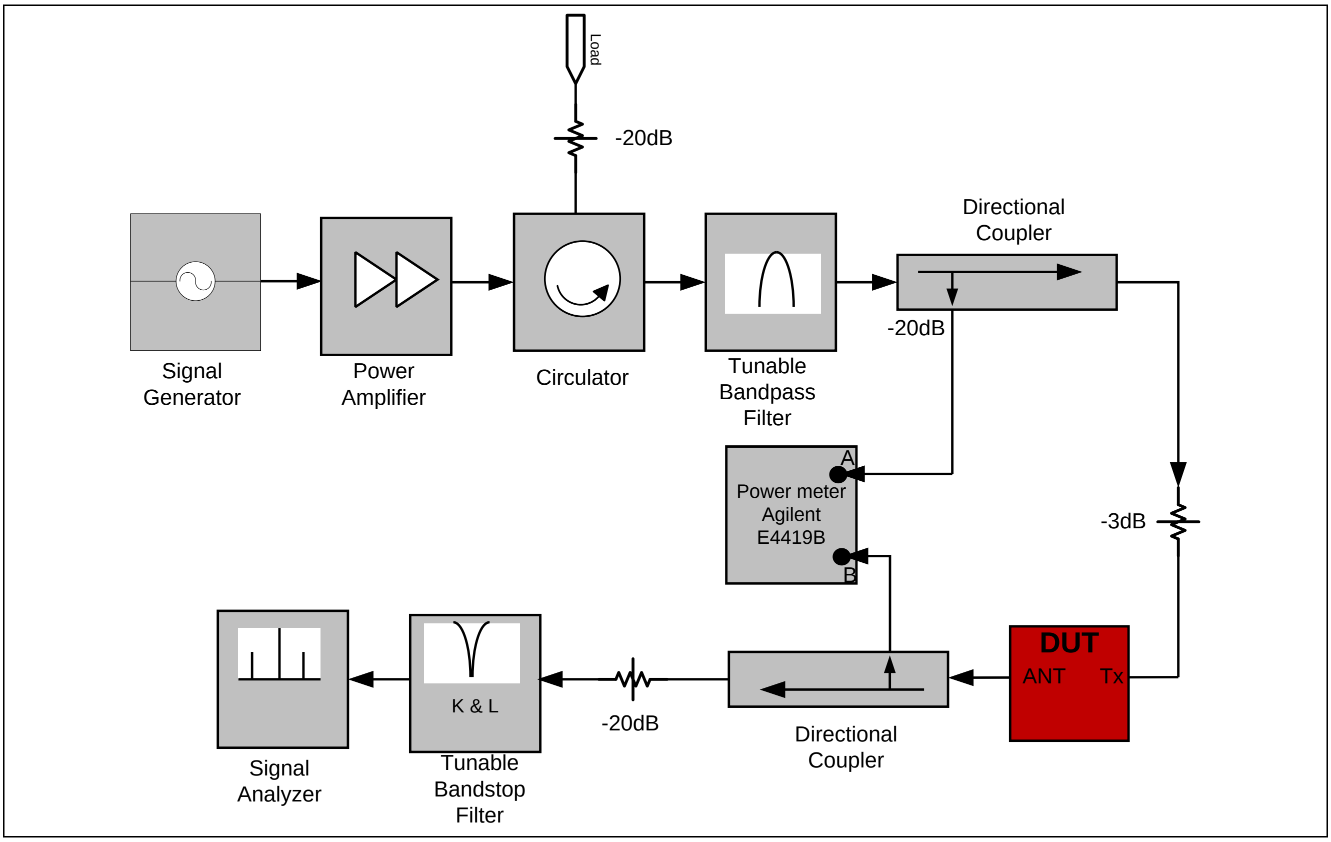

Figure 15 Set-up for harmonics measurement

The results for the harmonic generation at 830 MHZ are shown in Figure 16 (2nd harmonic) and Figure 17 (3rd harmonic) for all RF ports.

At the x-axis the input power is plotted and at the y- axis the generated harmonics in dBm.

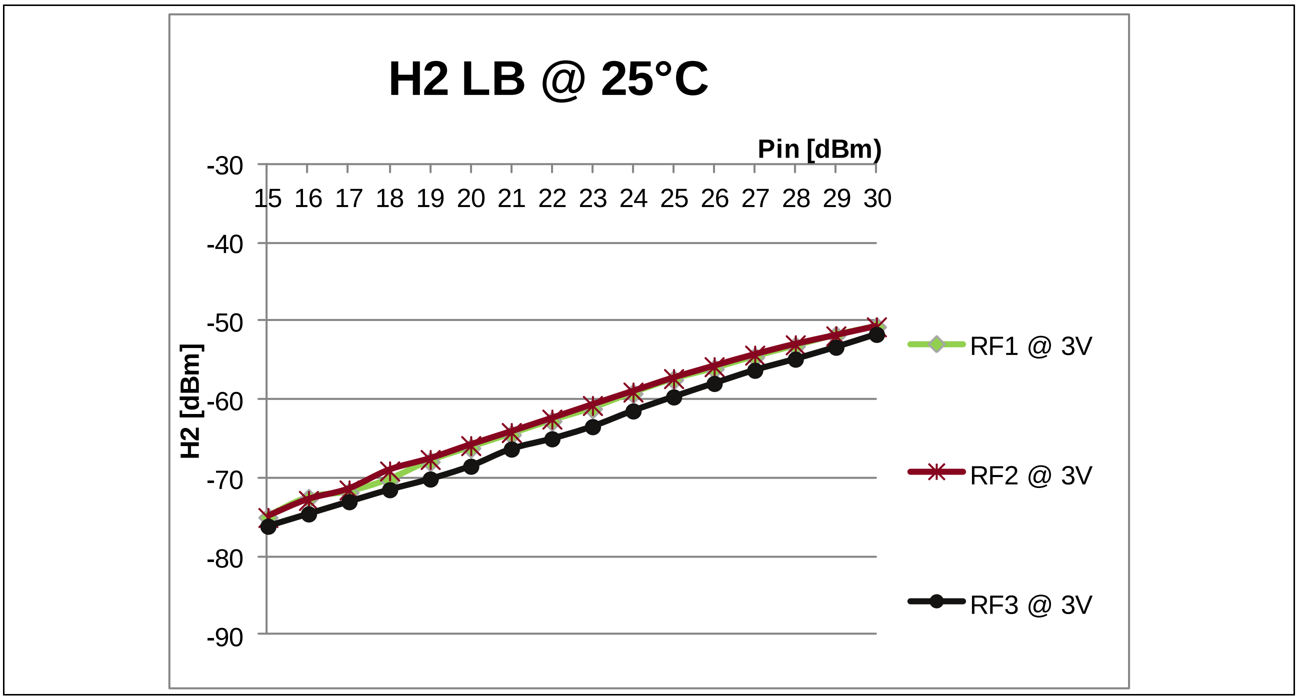

Figure 16 2nd harmonic at f_c=830 MHz

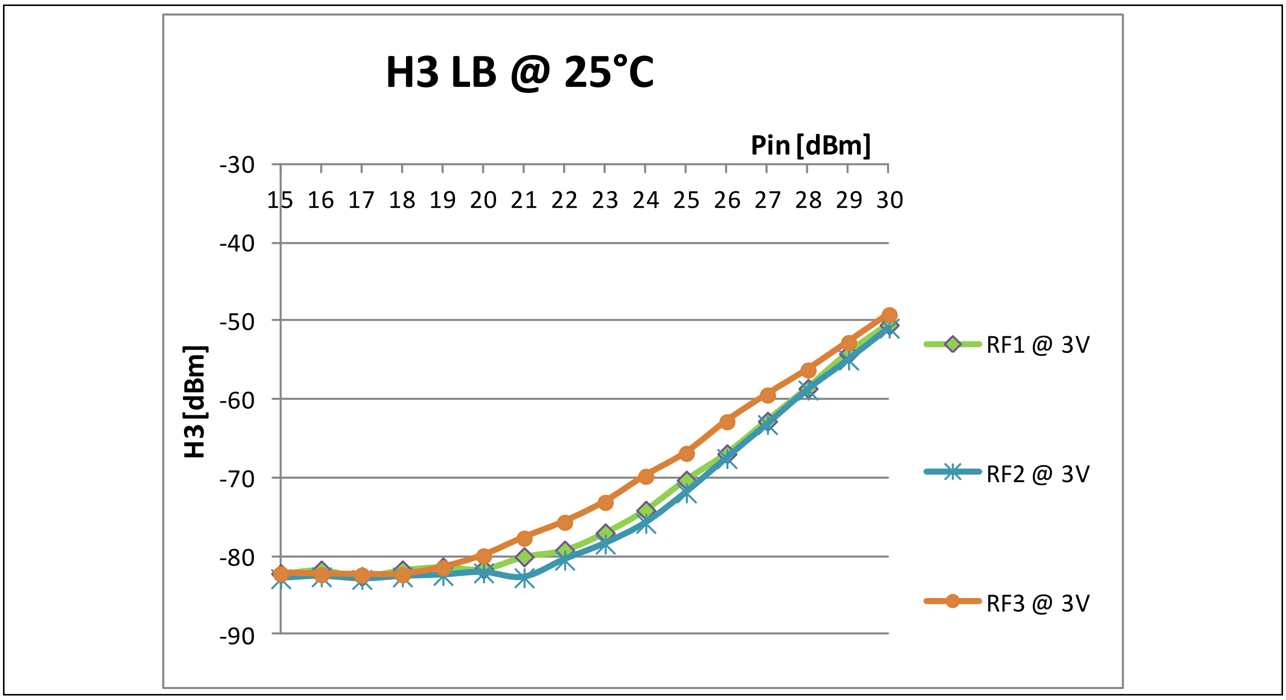

Figure 17 3rd harmonic at f_c=830 MHz

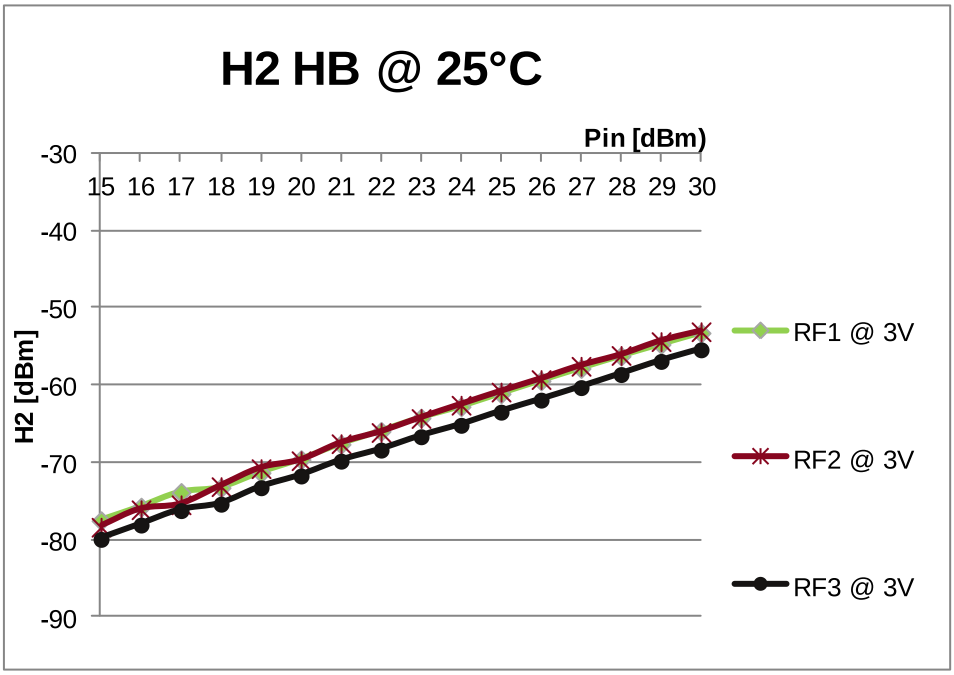

Figure 18 2nd Harmonic at f_c=1800 MHz

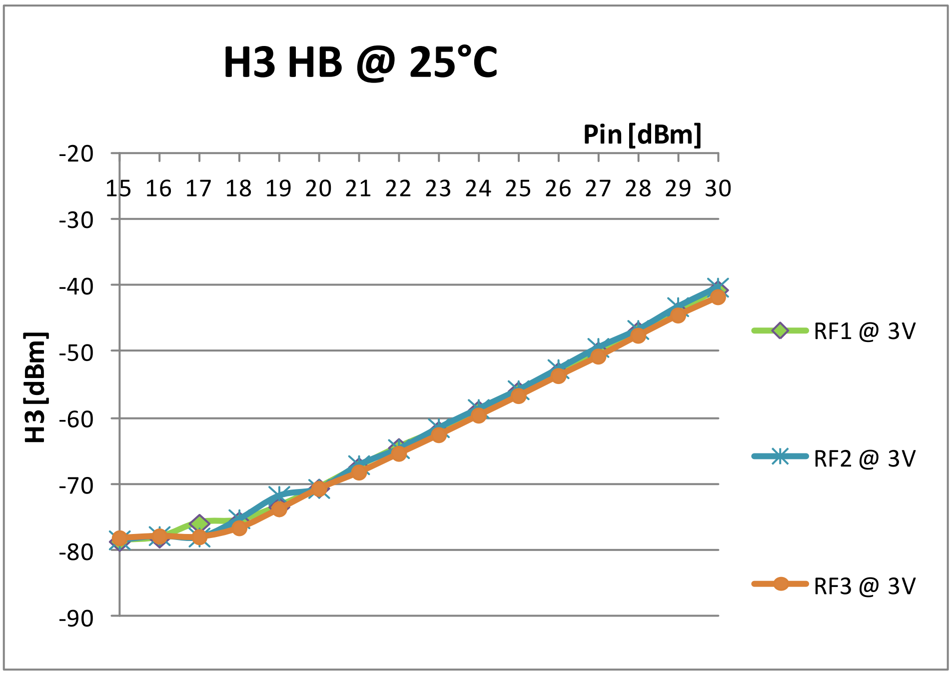

Figure 19 3rd Harmonic at f_c=1800 MHz

7 Switching time

7.1 Measurement Specifications

Switching On Time: 50% Trigger signal to 90 % RF Signal

Switching Off Time: 50% Trigger signal to 10% RF Signal

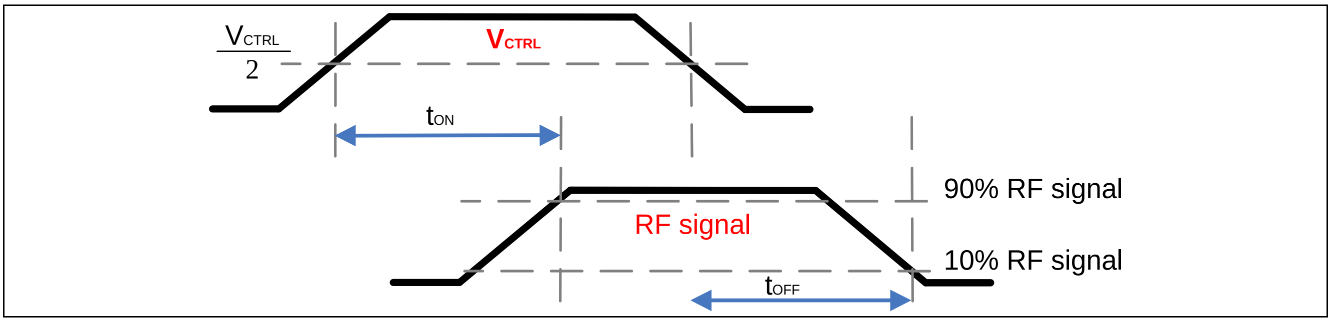

Figure 20 Switching Time

Rise time: 10% to 90% RF Signal

Fall time: 90% to 10% RF Signal

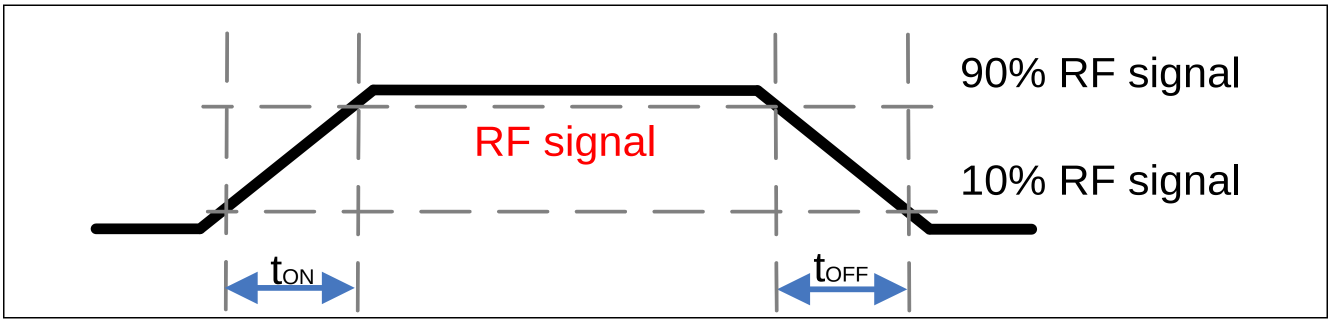

Figure 21 Rise/Fall Time

7.2 Measurement Setup

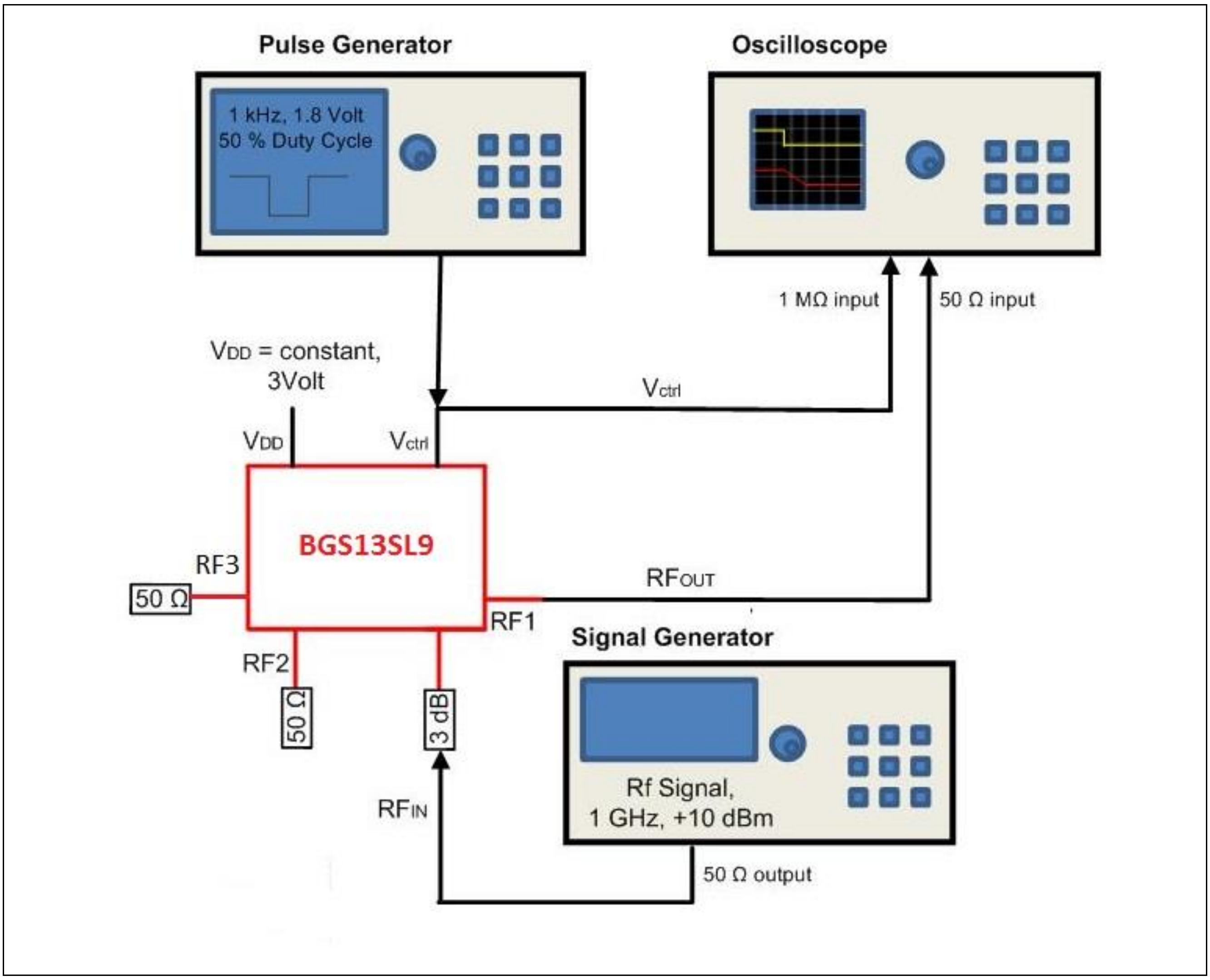

Figure 22 Switching Time Measurement Setup

7.3 Measurement results

The switching Time measurement setup consist of one pulse generator which generates a sqare wave with 50% duty cycle and an amplitude of 1.8 Volts, an oscilloscope which can detect the 1 GHz signal and the 1 kHz signal and one Signal generator which is set to an output signal of 1GHz with a power level 10 dBm.

If the oscilloscope can not detect the 1 GHz signal of the RF path, due to small bandwith, it is possible tu use a cristal oscillator in front of the oscilloscope (such a device detects any RF signal present at input and commutate that one) that the RF signal can be detected.

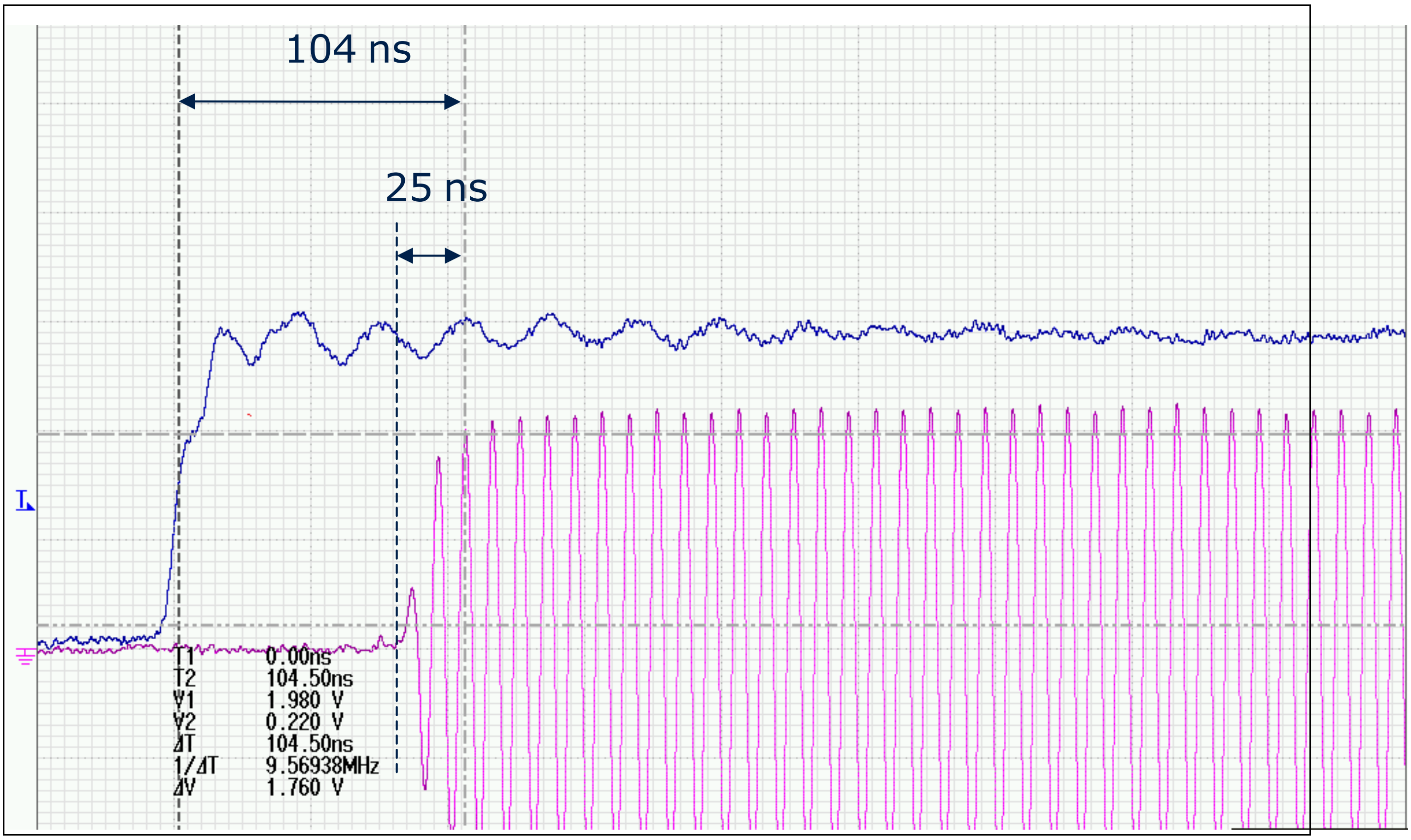

Figure 23 Screenshot of Switching Time Measurement BGS13SL9

Table 7 Switching time measurement results

	RF rise time (ns)	Switching time (ns)
BGS13SL9	25	104

8 Authors

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